2-9105

Queen's University at Kingston
Department of Chemical Engineering

CONTRACT REPORT NUMBER 1SU82-00258

CONTRACT REQUISITION NUMBER 23440-2-9105

CONTRACTOR QUEEN'S UNIVERSITY

DSS Contract No. 1SU82-00258

FINAL REPORT

The Construction and Activation of a Multireactor Synthesis Catalyst Testing Apparatus

December 1983

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Department of Chemical Engineering
Queen's University

32 pp

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MICROMEDIA

Introduction

A multireactor catalyst testing apparatus has been constructed between October 1, 1982 and September 30, 1983 as agreed under contract No. ISU82-00258 DSS File No. 05SU.23440-29105.

Under the agreement we had contracted to build at least three reactors: two plug flow and one slurry type. On agreement of the Scientific Authority we have not constructed any plug flow reactors but have chosen to build four slurry reactors.

The frame, panel and other auxiliaries have been prepared for four additional reactors to conform with our original design. Thus the number and types of reactors can readily be increased if future funding becomes available.

Report

Appendix "A" of the contract defines the objectives to be:

1) Design, construction, activation and calibration of a portable multireactor testing apparatus for Fischer Tropsch Catalytic reactions.

2) Validation of the apparatus in a series of routine tests on selected catalysts.

3) Completion of the Major Tasks to the satisfaction of the Scientific Authority.

Of the above objectives we have completed 1 and 2 as agreed and await the report of the Scientific Authority concerning objective 3.

The Major Tasks are also outlined in Appendix "A" of the contract and we report on these in order.

TASK 1

Detailed designs of plug flow reactors for the study of the FT reaction.

The apparatus will be designed for a maximum temperature of 500°C and a maximum pressure of 3.5 kPa (500 psi). Each reactor will be able to operate independently at its own pressure, temperature, feed rate and feed ratio. The total number of reactors will be dictated by budget considerations. The minimum number will be two plug flow reactors and one slurry reactor.

Task 1 has been carried out as specified except that: a) no plug flow reactors have been built, b) four slurry reactors

have been constructed, and c) the slurry reactors have been designed so that at minimal expense they can be converted to recirculating, Berty type, gas phase reactors.

The reasons for not proceeding with the construction of Plug Flow reactors were that: 1) isothermal operation would be difficult and expensive to assure, 2) slurry reactors seem to be more and more attractive as a practical candidate for full scale development, 3) owing to the high heat capacity and the thorough mixing of the slurry, excellent temperature control is possible, and catalyst destruction owing to local "hot-spots" is prevented, 4) the slurry process has the highest flexibility in different operating conditions and consequently a wider product spectrum, allowing changes in market demands to be met, and 5) plug flow reactors are unsuitable for testing catalysts at high conversions. They are difficult to run, especially for iron catalysts, because of problems arising from catalyst aging, coke formation, and catalyst disintegration.

In report No. 3, dated January 1983, we confirmed the agreement of the Scientific Authority to this change. Detailed drawings of Slurry reactor are shown in Figures 1, 2 and 3.

TASK 2

Detailed designs of apparatus configuration and layout.

This will involve a schematic of the overall system including all reactors, instruments and control devices. The apparatus drawings will describe a portable support structure and indicate the placement of all reactors and instruments.

Task 2 has been carried out in full. Attached to this report are updated drawings of the apparatus which include the minor changes in design which were implemented during construction and commissioning of the apparatus. The apparatus is built, on four frames, on wheels for transportability but is fixed to the laboratory floor during operation. Also included is a schematic of the analytical part of the equipment with the data flow showing the position of the purchased computer.

TASK 3

Specification of all instrumentation and control devices according to the drawings of Tasks 1 and 2 and ordering of these items.

Task 3 has been carried out in full and lists of equipment purchased have been included in monthly reports. Table 1 reiterates all the monthly purchases as reported during construction.

Due to the fact that we were able to dedicate a Capillary Chromatograph bought with other funds to this apparatus we requested and received permission from the Scientific Authority

for the purchase of a minicomputer and disc storage device. These allow us a great improvement in data collection and in the interpretation of results as well as reducing the costs of hardware which would otherwise be necessary. The net result is a greatly improved apparatus at no additional cost.

TASK 4

Construction of the portable support structure according to the apparatus layout design from Task 2.

Task 4 has been carried out in full.

TASK 5

Construction of the plug flow reactors and slurry reactors according to the designs from Task 1.

Task 5 has been carried out in full with the change that no plug flow reactors have been built.

TASK 6

Assembly of the constructed equipment, instrumentation and control devices into the portable support structure built in Task 4.

Task 6 has been carried out in full.

TASK 7

Initial testing of all individual items of equipment and instrumentation.

This will include pressure testing all reactors, lines and high pressure receiving vessels. All instruments and control devices will be tested to ensure that they are in working order.

Task 7 has been carried out in full and faulty items replaced under warranty.

TASK 8

Calibration of all measuring and control devices.

This will include all pressure regulators, flow controllers, temperature controllers, CO monitor and gas chromatograph. Operating range of the apparatus has been designed for:

- maximum temperature of 500°C with a minimum of 40°C
- maximum pressure of 3.5 KPa (500 PSIG) with a minimum of 0.2 KPa (30 PSIG)
- maximum flow for each gas is 3.00 SLPM with a minimum of 0.10 SLPM
- High Temperature Receiver maximum temperature of 150°C and a minimum of Room temperature

- Low Temperature Receiver has a maximum of 35°C and a minimum of -5°C
- Reactor magnetic drives have a RPM range of 0 to 2,000.

Task 8 has been carried out in full. The Capillary Chromatograph which has been assigned to the apparatus has also been interfaced with the minicomputer and the data system of the chromatograph has been made to sequence analytical operations on the equipment. This work was not funded by the contract but is dedicated to the operations of the apparatus.

TASK 9

Commissioning runs on the testing apparatus to ensure that each reactor can be operated independently, as described in Task 1, for a period of 100 hours under standard process conditions.

Task 9 has been carried out in full.

TASK 10

Formulation of routine operating procedures for the completed testing apparatus.

The routine operating conditions selected - pressures, temperatures feed rates, feed ratios, time, catalyst size - will require final approval of the Scientific Authority. These will also include provisions for testing catalyst sensitivity to poisons, such as water and hydrogen sulfide in the feed, as part of the routine operating conditions.

Gaseous products, from each reactor in turn, will be analyzed on an automated Gas Chromatograph dedicated to this purpose. On this basis the percent conversion, hydrogen utilization ratio and contraction will be calculated. Total effluent gas volume will be measured on wet test meters at the outlet of each reactor. Liquid hydrocarbon and aqueous phase yields will be routinely weighed to complete mass balance computations.

In cases where a more detailed analysis of the liquid products is required, analysis by GC/MS or capillary GC will be arranged.

Task 10 is very broad and demanding. The standard conditions which will be used for iron catalysts are 250 psi, 300°C and 1:1 H_2 to CO ratio and at a space velocity of 400 v/v/hr. There is however a great deal of flexibility built into the apparatus and we intend to deviate from these conditions whenever we feel that catalyst performance may be improved by such a change.

The sensitivity to poisoning can be tested at any time since each reactor is designed for three input flows; one for H_2,

one for CO and the third for gases such as CO_2, H_2S, N_2, etc. which might act as co-reactants, poisons or dilutants. No standard conditions for poisoning studies have been established. This item will require an experimental program to define.

EXPERIMENTAL

The principal components of the apparatus are shown in Drawing number 1. The apparatus is designed for continuous operation and is highly automated.

Input gas flowrates are individually controlled by mass flow controllers. The combined feed gases are then fed into the reactor with the reactor pressure being controlled by a back pressure regulator. A Thermocouple is positioned in the slurry in each reactor, allowing good temperature control by means of an external heater.

Output lines from the reactors are kept at an elevated temperature to prevent plugging by waxy product. The liquid waxes are collected in the high temperature receiver, with the gases from the high temperature receiver going to the low temperature receiver where they are condensed. The back pressure regulator allows the uncondensed gases from the low temperature receiver to go through the wet test meter where it is metered.

Gas samples from the exit stream are taken automatically at an appropriate frequency for chromatographic analysis. Gas samples are taken automatically under the control of an SP4270 chromatography data system. Gases are analyzed by a Carle SX 1156 under the conditions given in Table 2. The chromatographic reports from the SP4270 are sent to the apple II+ which is programmed to receive this data and writes it to disk as they are produced.

The condensed products are drained from the low and high temperature receivers every 24 hours. The liquid products are then separated, weighed and analyzed, using the Varian 6,000 capillary GC with auto sampler. Oils and waxes are analyzed under the conditions given in Table 1. All resulting analytical information plus sample weights, gas flows and other operating parameters are transferred to disc via the minicomputer.

Programmes written for a similar research effort funded by NSERC will then be used to produce mass balances, product distribution plots, conversion, utilization, contraction and a number of other values which are important to the evaluation of catalyst performance.

Thus by dedicating some equipment and much know-how available in our laboratories to this apparatus we have been able to convert an apparatus with rudimentary analytical facilities to

a high class testing apparatus. We will continue to have the GC/MS apparatus available for the identification of individual compounds in the product mix.

TASK 11

Completion of tests on Four FT catalysts, supplied by the contractor to demonstrate successful operation of the testing apparatus.

These will be tested under the routine operating conditions determined in Task 10. A detailed description of the results of this list will be included in the final report.

RESULTS AND DISCUSSION

Under the original agreement the gaseous products from each reactor were to be analyzed on an automated Gas Chromatograph dedicated to this purpose. On this basis, the percent conversion, hydrogen utilization ratio and contraction will be calculated. Total effluent gas volume will be measured on wet test meters at the outlet of each reactor. Liquid hydrocarbon and aqueous phase yields will be routinely weighed to complete mass balance computations. A cobalt catalyst and Eicoson as support was run at 60 psi, 200°C, 2:1 H_2 to CO ratio and 200 v/v/hr. These will be the standard conditions for Cobalt catalysts.

The catalyst was pretreated before the run at 200°C, 50 psi, H_2, and 70.5 hours. At these conditions we observed no major problems of catalst being taken over into the High temperature receivers. Although we had problems of wax plugging at the beginning of the run, these were overcome and the reactor performed as expected. The mass balance computations on this run are as follows:

Mol Percent Conversion of CO	51.7 %
Hydrogen/CO Utilization Ratio	2.18
Contraction	46.58%
Total Effluent Output Gas Volume	553.2 L
Total Weight % Recovery	102.2 %
Liquid Hydrocarbons Yields	121.7 gm
Aqueous Yields	223.3 gm

These results appear to be normal under the set conditions

For further detailed information on the computer programs used and plots that can be obtained with this information, refer to: "The Effect of Time on Stream and Feed Composition on the Selectivity of a Cobalt Fischer-Tropsch Catalyst" by B. Sarup and B.W. Wojciechowski. A copy will be provided with this report. As to the losses and mechanical wear of the catalysts, more time and study will have to be done than the one run performed. Only one Fischer-Tropsch catalyst was tested due to the time limitations, delays in equipment delivery, and waxing

problems that were encountered. However, the testing was sufficient to demonstrate that the equipment meets its design requirements and operates satisfactorily.

TASK 12

Preparation of monthly progress reports to be received by EMR by the fifteenth of each month.

Task 12 has been fully carried out.

TASK 13

Presentation of the results of this project including a complete description of the apparatus and catalyst test results at a seminar to be scheduled at CANMET, ERL.

Task 13 will be carried out at a time convenient for CANMET and Queen's personnel.

TASK 14

Preparation of a detailed final report to include a description of all Tasks and a final statement to summarize total expenditures.

Task 14 is hereby completed.

Table 1

Conditions for Capillary Chromatography

Gas chromatograph:	Varian 6000
Column:	30 m x 0.25 mm, SE-54 capillary
Carrier Gas:	1.0 ml/min U.H.P. N_2 (99.999 %)
Temperature program:	35°C for 10 min then 3°C/min to 300°C
Injection:	200:1, split injection at 300°C
Sample size:	0.5 µl
Detector:	FID
Analysis time:	approximately 3 hours

Table 2

Conditions for Gas Analysis

Gas chromatograph: Carle SX1156

Columns:

No.	Separation	Description
1A	C_3 - C_5	27% BIS(EE)A + 3.5% Carbowax 1540 + 6.5% DC 200/500 on chromosorb PAW 60/80 mesh. Length 18'.
1B	C_3 - C_5	OPN/Porasil C, 80/100 mesh, Length 3.5'.
2	CO, C_2H_2, C_2H_6	Porapac Q, 50/80 mesh, Length 6'
3	H_2 from all other components	Molecular sieve 13X , 45/60 mesh, 7'. The hydrogen transfer system transfers H_2 into an auxillary N_2 carrier gas.

Carrier gases: 30 ml/min V.H.P. N_2 (> 99.9%), for H_2 only.
30 ml/min V.H.P. He (> 99.995%)

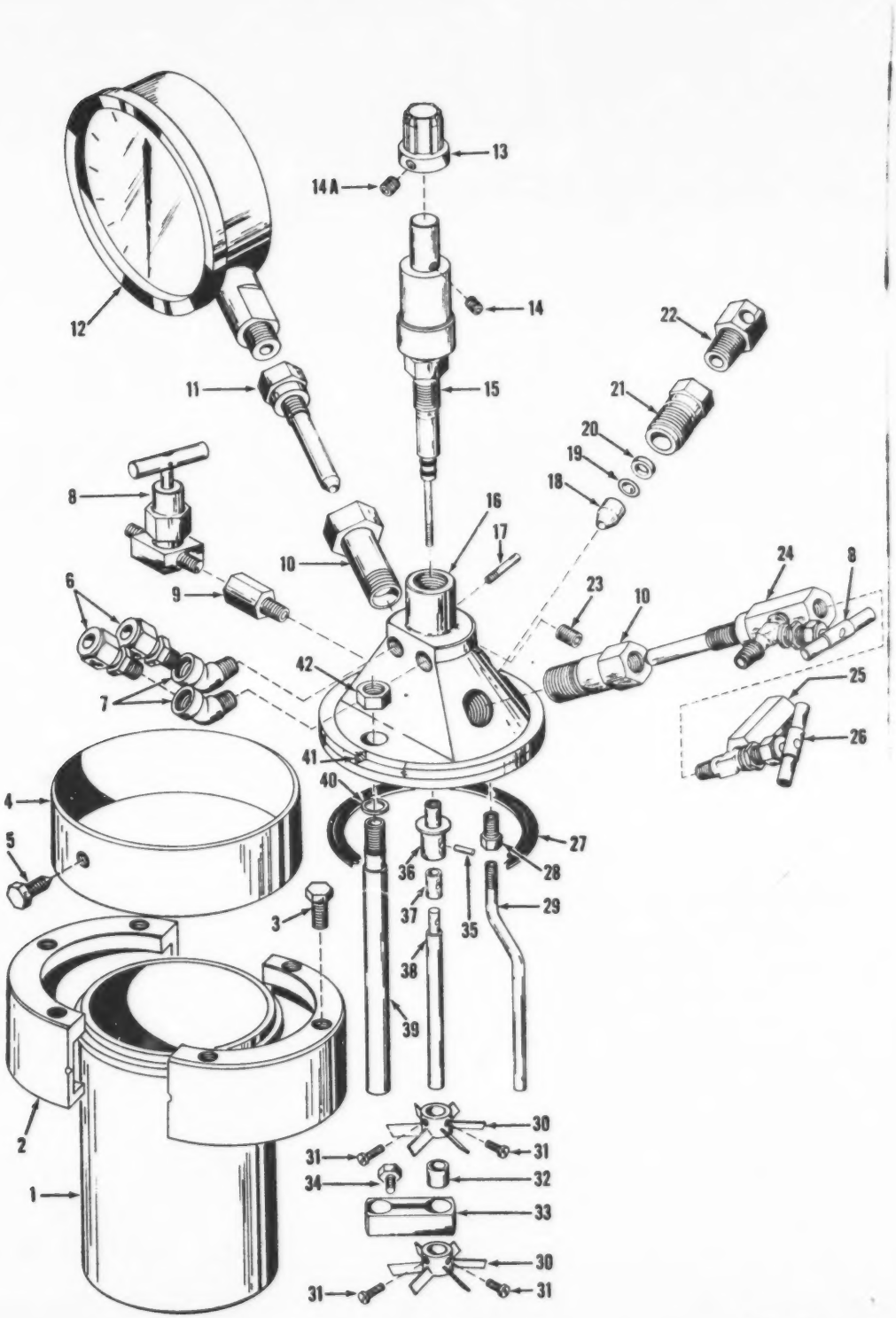
Detectors: 2 TCD's

Analysis time: 30 minutes

Injection: On-line automatic sampling

Sample size: 1 ml

PARTS FOR ONE AND TWO LITER REACTORS



4645 and 4646 One and Two Liter Bombs

FIGURE 1

Parts List for One Liter Reactor

From Figure 1

Key No.	Item
1	Bomb cylinder
2	Split ring
3	Cup screw
4	Drop band with screw
5	Cone pointed screw
6	Tube connector
7	Elbow, 45° NPT
8	Needle valve
9	Valve extension
10	Bushing
11	Valve adapter
12	Pressure gage
13	Splined coupling
14	Set screw
15	Stirrer drive
16	Bomb head
17	Leak detector tube
18	Orifice cone
19	Rupture disc
20	Orifice ring
21	Rupture disc plug
22	Safety tee
23	Plug, 1/8" NPT
24	Valve adapter
25	Adapter
26	Angle valve
27	Head gasket
28	Nut for dip tube
29	Gas inlet tube
30	Impeller
31	Set screw
32	Bushing
33	Stirrer bracket
34	Cup screw
35	Pin
36	Coupling
37	Shaft Bushing
38	Shaft
39	Thermo well
40	Gasket, silver
41	Compression ring
42	Hex nut

A1120HC2 and A1120HC3 MAGNETIC DRIVE ASSEMBLIES

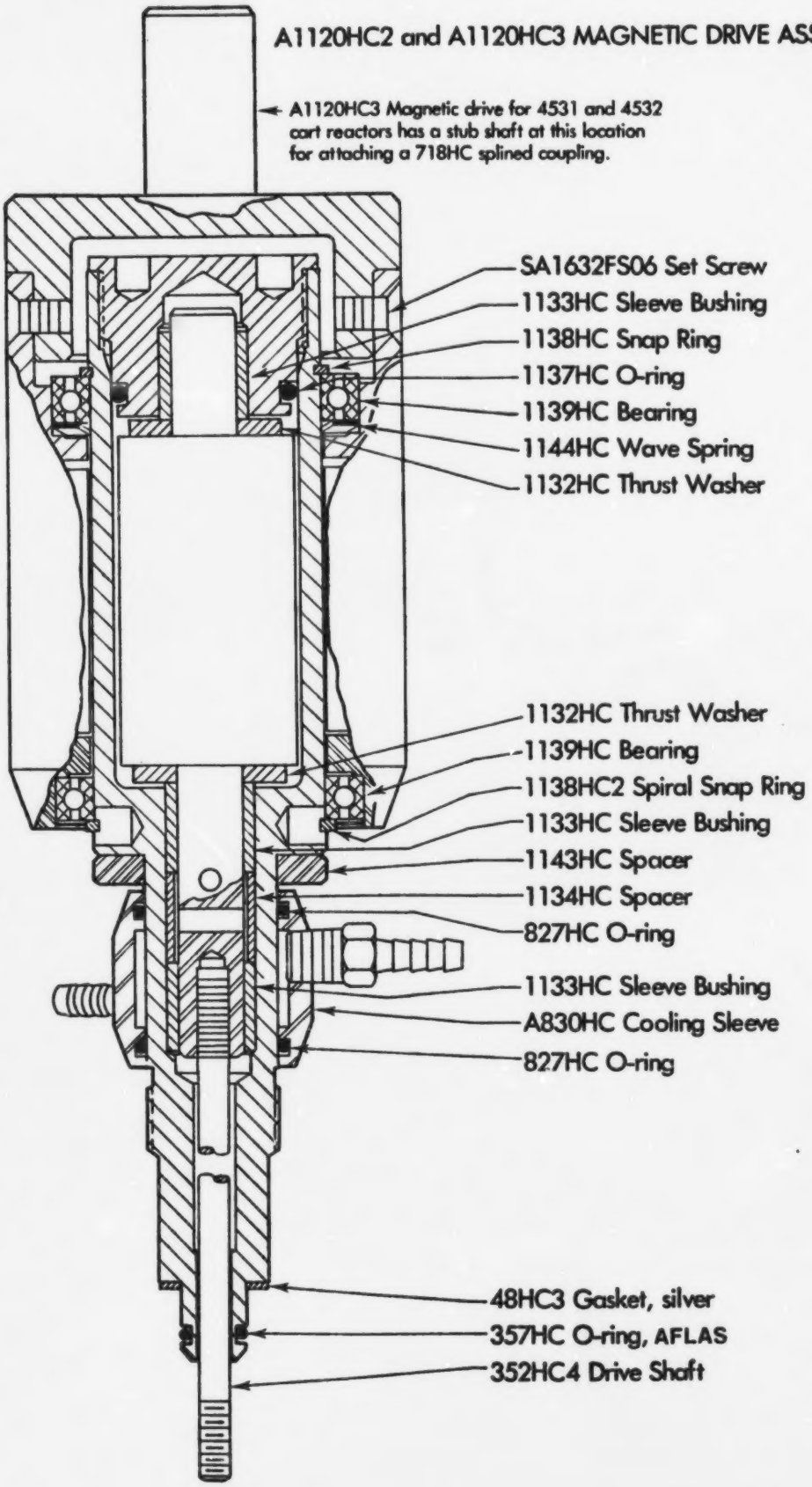


FIGURE 2

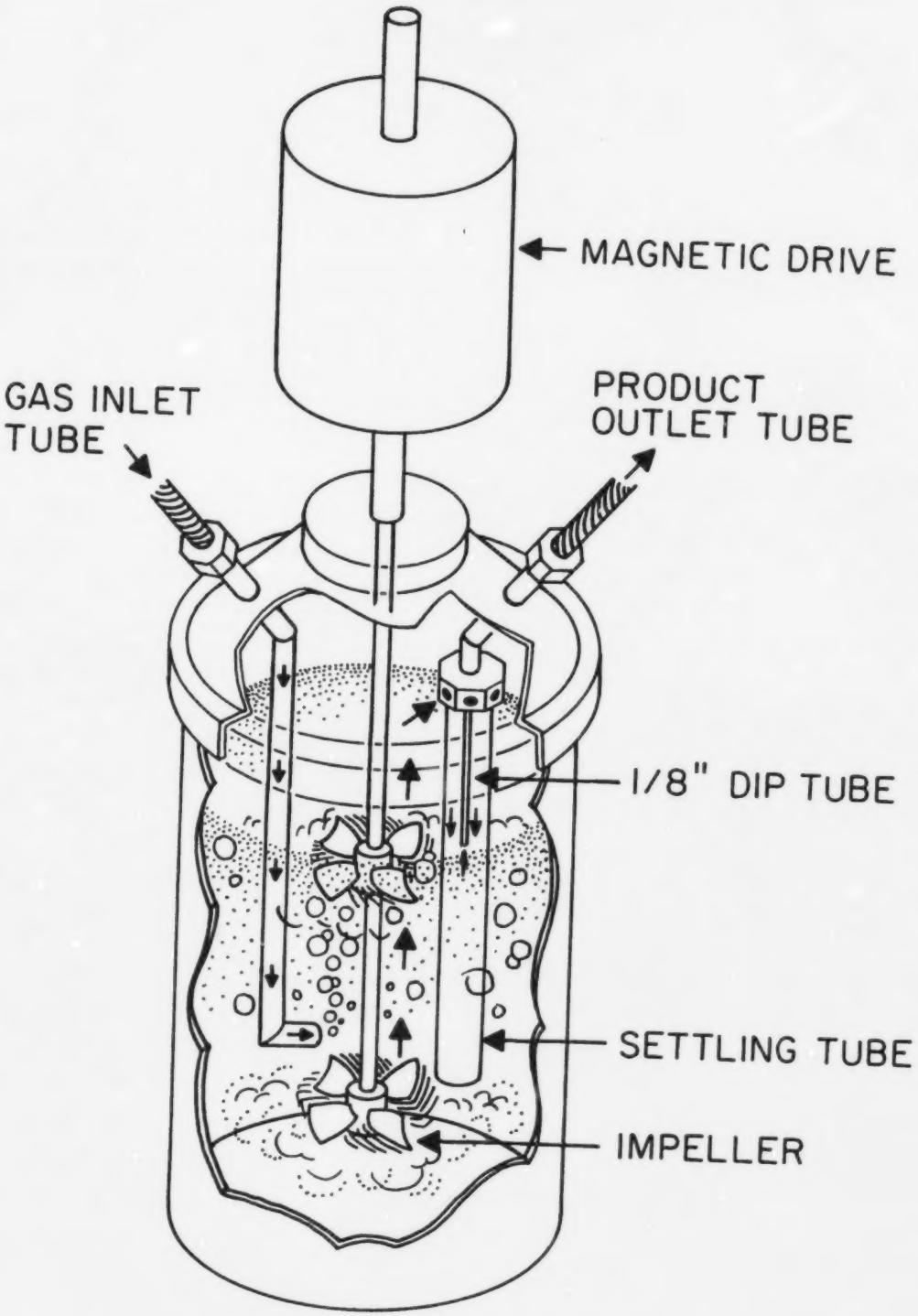
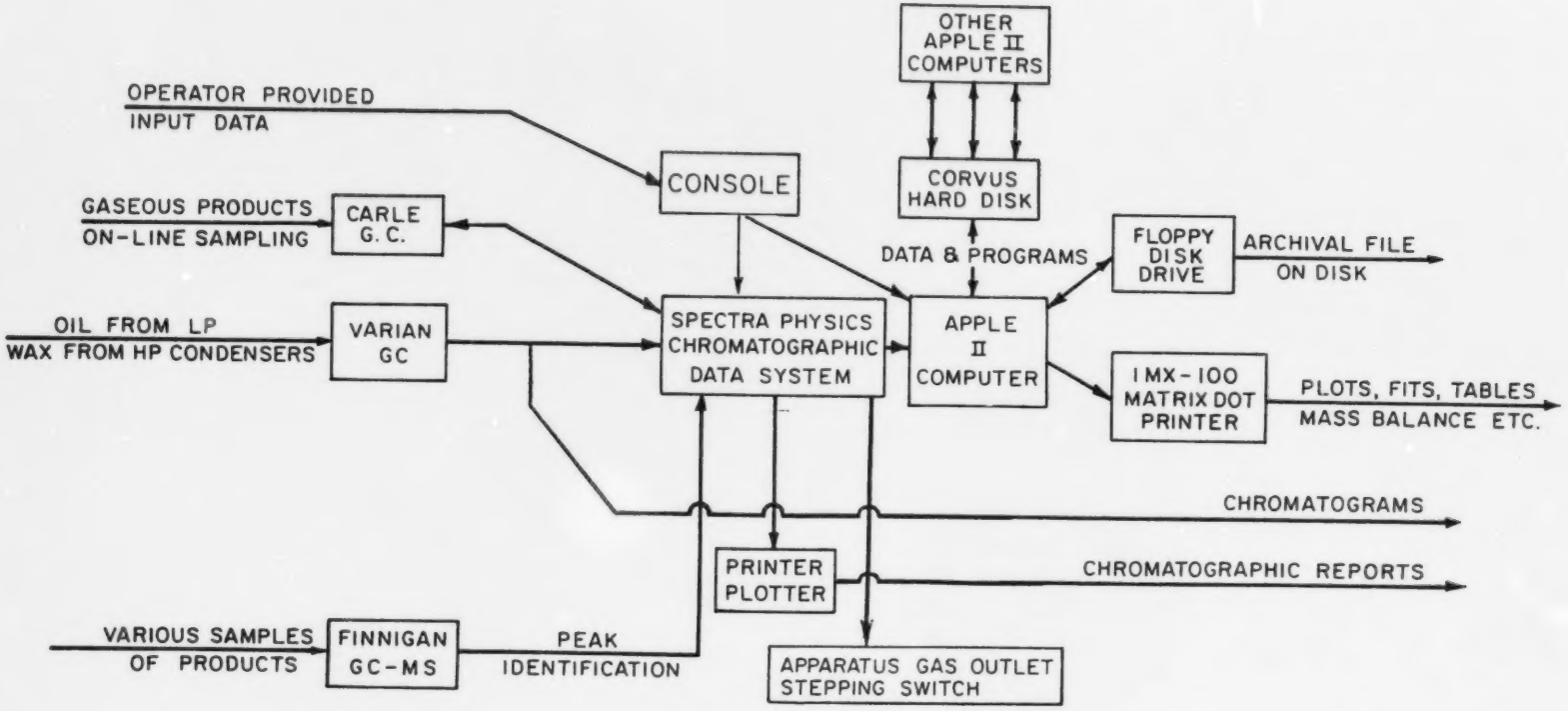


Figure 3

SLURRY REACTOR GAS FLOW, SHOWING LIQUID SEPARATION



SCHEMATIC OF ANALYTICAL EQUIPMENT AND DATA FLOW

FINANCIAL

The budget for this project was as shown in Appendix "B" of the contract. In Table 3 we show the expenditures as incurred.

Table 3

	Item	Budget	Actual as of November/83
A	Labour	$ 23,004	$ 22,910.73
B	Materials & Supplies	3,000	3,000.00
C	Machine Shop Charges	3,000	---
D	Equipment	107,720	110,086.39
E	Authorized Travel	2,400	441.46
F	Overhead	7,849	10,534.42
	TOTAL	$ 146,973	$ 146,973.00

In the budget we were allowed to move sums from item to item except for the salaries. We also agreed not to exceed the total. Table 1 shows details of the equipment expenditures and the corresponding budgeted amounts where appropriate. The total sum has not been exceeded.

SUMMARY

The contract has been carried out as specified. Additional analytical equipment and computer programs which have been developed at Queen's make the new testing facility much more powerful than originally visualized. This fortunate confluence of resources allows us to test from one to four catalysts per week and to evaluate their performance in great detail.

Relatively inexpensive modifications will convert the available slurry reactors to Berty type, gas phase, CSTR's while maintaining the capability to operate as slurry reactors. This project has been proposed as part of a follow-up programme.

The support facilities, reactor frame, control panel, etc are set up so that four more reactors of any type may be added if this is necessary. The analytical setup would require some upgrading to cope with the additional sample throughput but such a set of four additional reactors should cost no more than approximately $90,000 (1983 prices) including the analytical equipment (hardware costs only).

Thus we are prepared to produce an 8 reactor apparatus for a grand total of less than $200,000 cost in hardware including analysis and computational facilities. This comes to approximately $25,000 per reactor with attached services: a remarkably low figure.

Four More Slurry Reactors

Each Reactor	approx.	$ 10,000	$ 40,000
Second Carle		$ 13,000	$ 13,000
Second Data Sample		$ 6,000	$ 6,000
Second FID		$ 3,000	$ 3,000
Second Data Station (If Apple & Isaac)		$ 12,000	$ 12,000
Fittings & Piping		$ 10,000	$ 10,000
		TOTAL	$ 84,000
		Contingency	$ 5,000

Summary of Total Purchases

Drawing Number	Item	Supplier	Price as Proposed	Price as Ordered
1,1,1	2,10,8	Ottawa Valve & Fitting Ltd.	$ 4,588.60	$ 3,952.57
	Tubing	Graves Brothers Ltd.	240.00	285.00
1,1	1,11	Armatek Controls Ltd.	5,396.00	5,396.00
3	4	Thermo Electric	1,900.00	2,484.00
3	4	Omega Engineering Inc.	1,900.00	610.00
3,3,3	7,5,6	Electro Sonic Inc.	699.60	1,076.68
2 & 5	5	Calibrated Instruments Inc.	400.00	400.00
1	3, 16	Levac Supply Ltd.	262.20	248.60
	Aluminum Plate	Alcan	104.00	104.00
3	1	Canadian Tire Co.	40.00	44.08
	Data System	Technical Marketing Assoc	10,000.00	8,767.00
5	4	Technical Marketing Assoc	775.00	1,587.00
3	13	Nedco	837.30	826.50
1	4	Unit Instruments	11,250.00	10,800.00
1,3,3	7,16,3	Thermo Electric	825.00	2,484.28
	Manifold & Reg.	Canox	1,650.00	1,436.28
1,1	12,5	Cowper Inc.	541.50	609.75
1	6	McGregor Instruments	750.00	750.00
N2	Regulator	Chromatographic Specialties	142.90	142.90
3	14	Technical Marketing	14,000.00	12,850.00
3	2	Electro Sonic	75.00	478.32
	Balance	Fisher Scientific	2,481.25	1,775.00

Summary of Total Purchases (cont.)

Drawing Number	Item	Supplier	Price as Proposed	Price as Ordered
4	6+8	Parr Instrument (Reactors)	$ 22,000.00	$ 27,742.50
	T/C wire	Emmans Limited	100.00	91.20
	Cooling hose	Levac Supply	18.00	18.00
	N_2 Regulator	Chromatographic Spec.	142.90	165.80
	Paint	Sherwin Williams	7.41	7.41
	Additional Power	Queen°s (Contingency Funds)	2,400.00	2,400.00
	Fittings	Ottawa Valve	459.20	625.88
	Copper tubing 1/4" + 1/8"	Levac Supply	27.90	52.90
4	5	B + B Motor + Control Corp.	240.00	391.06
5	2	B + B Motor + Control Corp.	600.0	249.60
	Power Supply	Electrosonic Inc.	300.00	450.00
4	7	Cantrus	Misc.	42.50
	Power Bar	Canadian Tire	Misc.	40.00
	Separatory Funnel	Canlab	Misc.	125.20
	Specimen Bottles	Fisher	Misc.	104.10
	Paint	Sherwin Williams	Misc.	7.41
	Heating Tape	Electrothermal	400.00	629.60
	Fittings	Ottawa Valve	Misc	401.80
	1/4" SS Tubing	Graves Brothers	Misc.	69.00
	Stepping Switch	Herbach and Rademan	Misc.	39.00
	1/8" Copper Tubing	Levac Supply	Misc.	27.00

Summary of Total Purchases

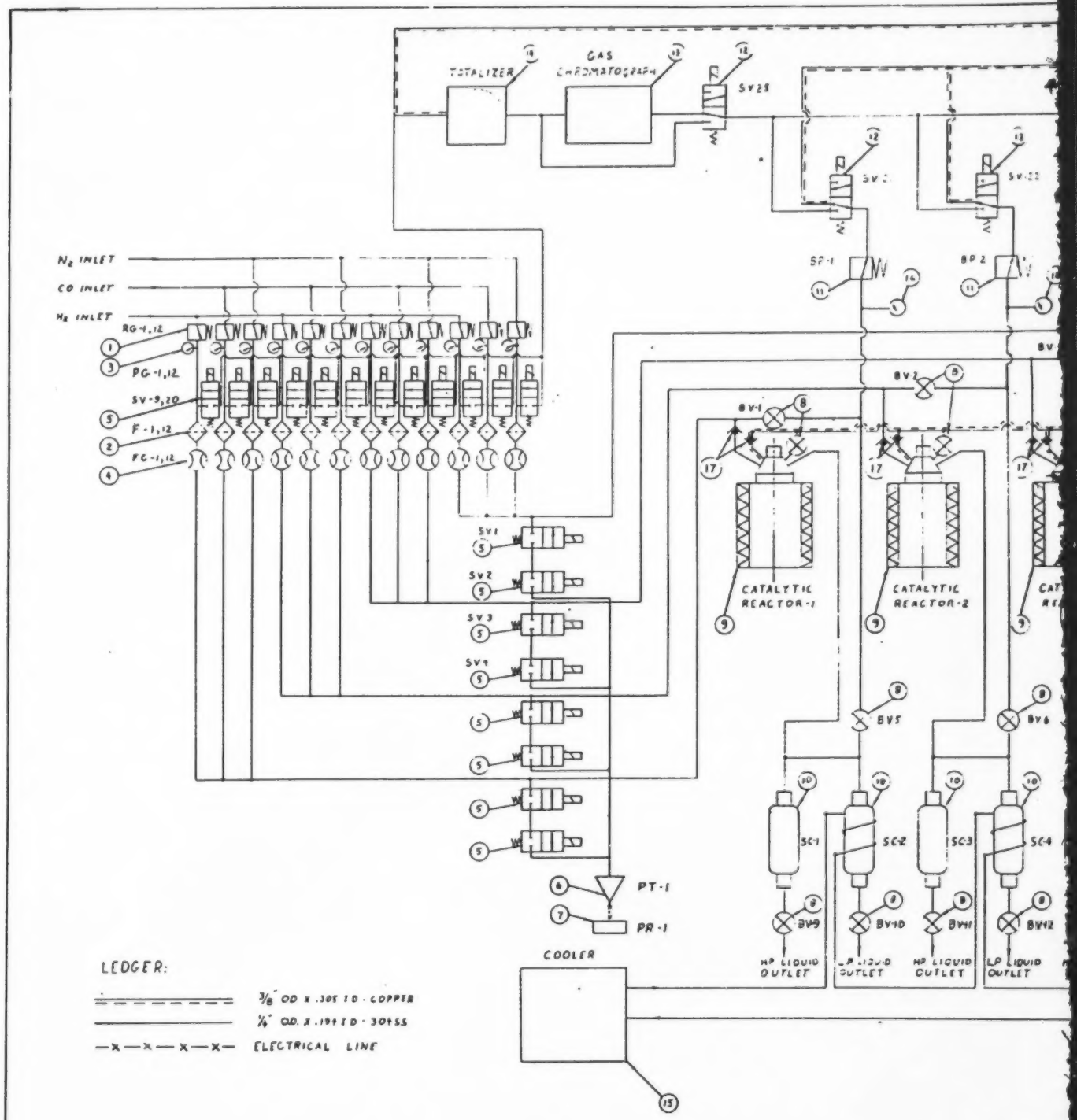
Drawing Number	Item	Supplier	Price as Proposed	Price as Ordered
	PC Board	Electronic Packaging	Misc.	$ 70.00
	Potentiometers	Electro Sonic	Misc.	202.69
	Tachometers	Power Ins.	Misc.	261.00
	1/4" Tubing (ACR)	Marshall Refrigeration	Misc.	23.43
	Corvas Hardisk 20 MEG	Computer Innovations		9,745.52
	Apple IIe Starter System And Interfaces	Computer Innovations		
	Toggle Switches	Radio Shack		7.04
	Dymo Tape	Mills		3.05
	Drafting Paper	Wallneks		1.55
	Solid State Relays	Electrosonic Inc.		129.92
	T.C. Wire	Emmans		179.00
	12 VDC Transformer	Radio Shack		7.99
	Light & Flasher	CTC		12.28
	Omninet Interface	Computer Innovation		680.52
	Durabond Columns	Chromatographic Specialties		752.00
	SS Relays	Varion		66.00
	Electrical Boxes	CTC		30.00
	Pulleys & Belts	CTC		20.00
	Fittings	Ottawa Valve		202.00

Summary of Total Purchases

Drawing Number	Item	Supplier	Price as Proposed	Price as Ordered
	3/8" Copper Tubing	Levac Supply		$ 30.00
	Snap Rings	Baxters		2.41
	1/2" Fittings	Marshalls		15.00
	T.C. Probes	Omega		384.00
	Relays Exchange	Electrosonic Inc.		10.00
	Fittings	Ottawa Valve		30.20
	Pulleys	CTC		48.57
	Eicosane (Chemical)	Aldrich Chemical		119.00
	Ceramic Heaters	Thermcraft		88.80
	Electrical Boxes	C.T.C.		25.10
	Fittings	Ottawa Valve		19.62
	Insulation	C.T.C.		68.93
	Solenoids	Cowper Inc.		2,363.70
	Fittings	Marshalls		4.65
	Sproket	Canadian Bearing		27.65
	Wire	Kingston Electronic Supply		36.33
	Paint	C.T.C.		8.86
	Lights	Radio Shack		2.55
	2X Motors & Control	B & B Motor & Control		640.66
	Push Buttons	Electro Sonic		38.61
	Wrench & Solder	C.T.C.		29.00

Summary of Total Purchases

Drawing Number	Item	Supplier	Price as Proposed	Price as Ordered
	Switches & Fuses	Kingston Electronic Supply		8.88
	Cal. Gas	Matheson		529.50
	Power Backup	Technical Marketing		990.00
		November 1983 Total to Date		$108,692.41


TOTALIZER
GAS CHROMATOGRAPH
SV25
SV-1
SV-22
SP-1
BP 2
N_2 INLET
CO INLET
H_2 INLET
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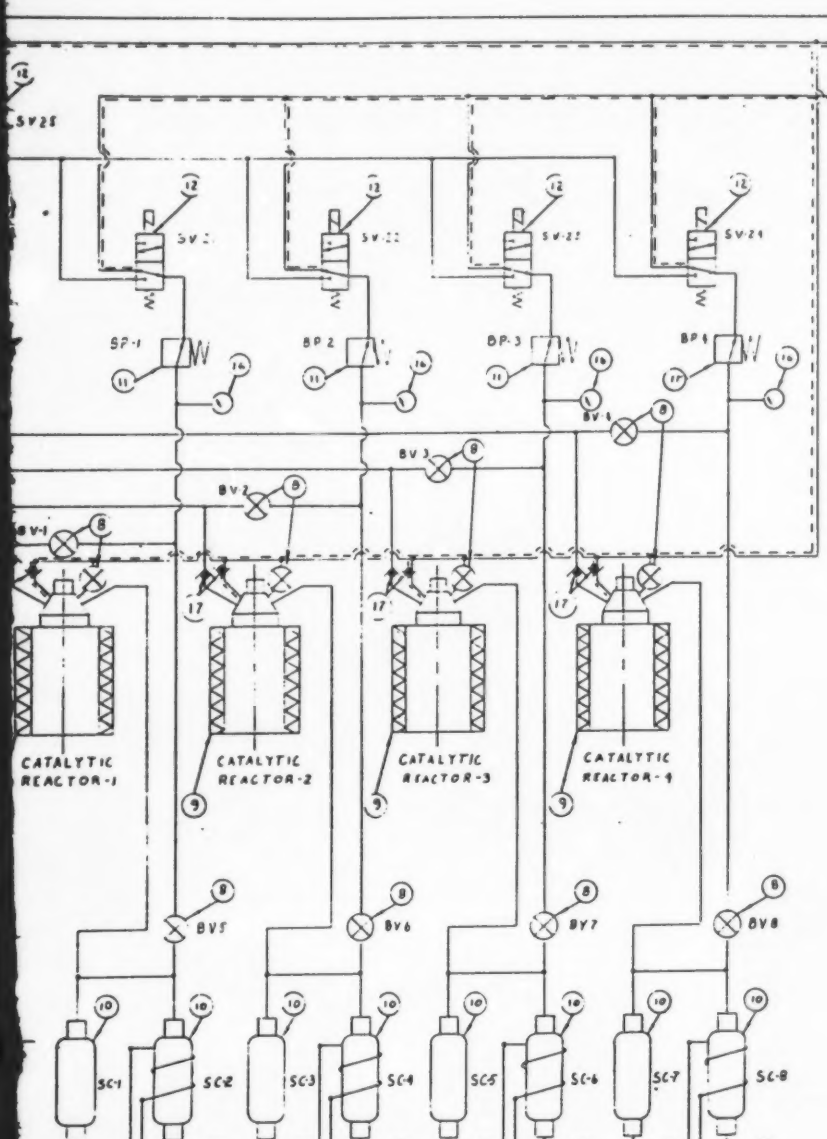
PG-1,12
SV-9,20
F-1,12
FG-1,12
SV1
SV2
SV3
SV4
BV-1
BV 2
BV5
BV6
CATALYTIC REACTOR-1
CATALYTIC REACTOR-2
SC-1
SC-2
SC-3
SC-4
BV9
BV10
BV11
BV12
HP LIQUID OUTLET
LP LIQUID OUTLET
HP LIQUID OUTLET
LP LIQUID OUTLET
PT-1
PR-1
COOLER
LEDGER:
3/8" OD X .305 I.D - COPPER
1/4" O.D. X .194 I.D - 304SS
ELECTRICAL LINE



NOTES:

DRAWING SHOWS A FOUR REACTOR SETUP FINAL ASSEMBLY WILL HAVE EIGHT CATALYTIC REACTORS.

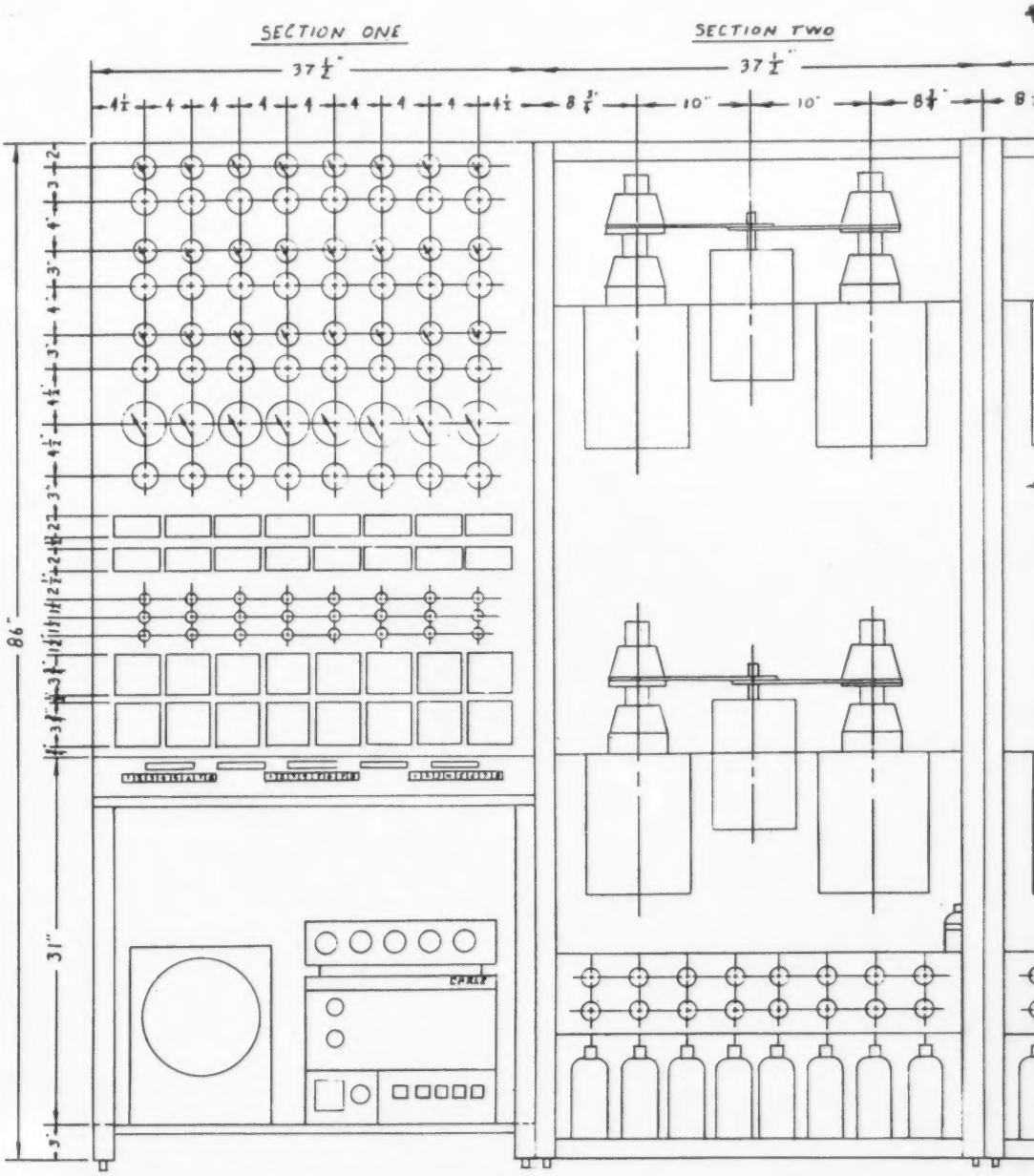
ITEM	QTY	DESCRIPTION	MFG'S NO.	REMARKS
17	8	CHECK VALVE -316 SS	SS-4C-1/8	NUPRO 5 PSI 1/8" TUBE CONN'S
16	4	PRESSURE GAUGE -316 SS	———	MATHESON, 3½" DIAL 0-600 PSI RANGE ¼" NPT
15	1	REFRIGERATED CHILLER	K-1283-00	NESLAB 1910 BTU/hr. TEMP. -5° to 35°C
14	1	WET-TEST METER	11-1664	FISHER 680 cc
13	1	GAS CHROMATOGRAPH	AGC 111	CARLE FOUR PACKED COLUMNS, HYDROGEN TRANSFER
12	5	THREE WAY SOLENOID VALVE - 316 SS	V54DA2075	SKINNER 0-150 PSID. ¼" NPT (F) CONNS
11	4	BACK PRESSURE REGULATOR - 316 SS	BPR-40-SS	VERIFLO 2-600 PSI RANGE ¼" NPT (F)
10	8	SAMPLING CYLINDER -304 SS	304L-HDF-4-500	WHITEY 500 cc CAPACITY ¼" NPT (F) CONNS.
9	4	CATALYTIC REACTOR	4532	PARR BENCH TOP 1 LITER REACTOR 1900 PSI @ 350°C
8	20	BELLOWS VALVE -316 SS	SS-4H	NUPRO ¼" TUBE CONNS (SWAGELOK)
7	1	PRESSURE READOUT	P16156	ANALOGIC 3½ DIGIT 0-5V
6	1	PRESSURE TRANSDUCER -1/2 PSI	204E	SETRA SYSTEMS, 0-500 PSI ¼" NPT (F) CONNS.
5	9	TWO WAY SOLENOID VALVE -316 SS	V52HLA2G502	SKINNER 0-500 PSID. ¼" NPT (F) CONNS.
4	12	MASS FLOW CONTROLLER -316 SS	UFC-1000	UNIT INS. 0-5 SLPM. ¼" TUBE CONN'S (SWAGELOK)
3	12	PRESSURE GAUGE -316 SS	———	MATHESON 2½" DIAL 0-600 PSI RANGE, ¼" NPT
2	12	INLINE FILTER -316 SS	"SS-4FT7-7	NUPRO. 7 MICRON. ¼" TUBE CONN (SWAGELOK) INLET & "TUBE STUB OUT
1	12	PRESSURE REGULATORS-316 SS	"1R 403	VERIFLO 0-600 PSI RANGE ¼" NPT(F)

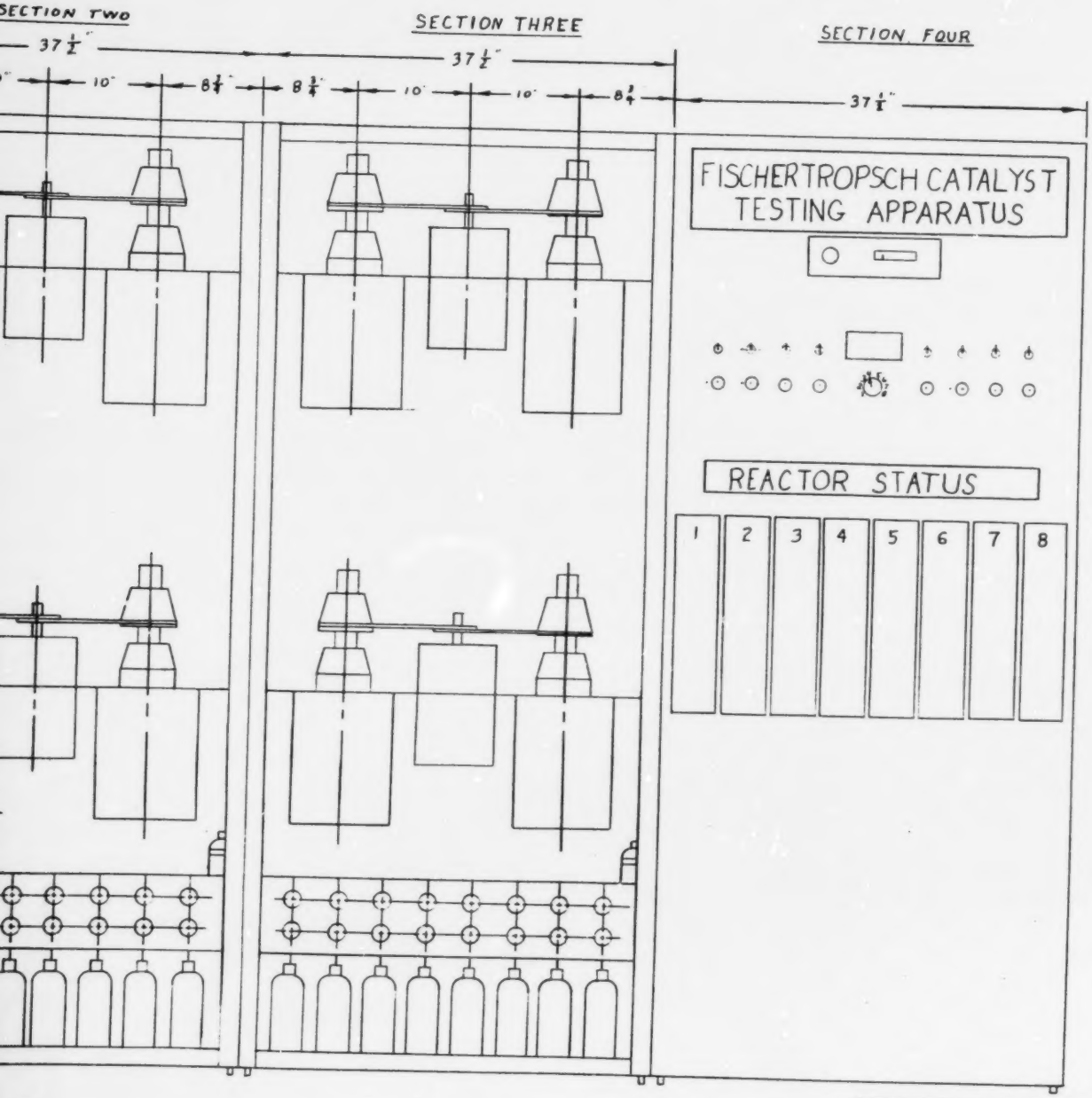
PARTS LIST

QUEENS UNIVERSITY
CHEMICAL ENGINERING
KINGSTON, ONTARIO

FLOW SCHEMATIC

NAME	CHECKED BY
O. OOSTEN	B.W. Wyerichuk
DATE	DRAWING NO.
SEPT. 26/83	1


SECTION ONE
SECTION TWO
37 1/2"
37 1/2"
86"
31"
FRONT



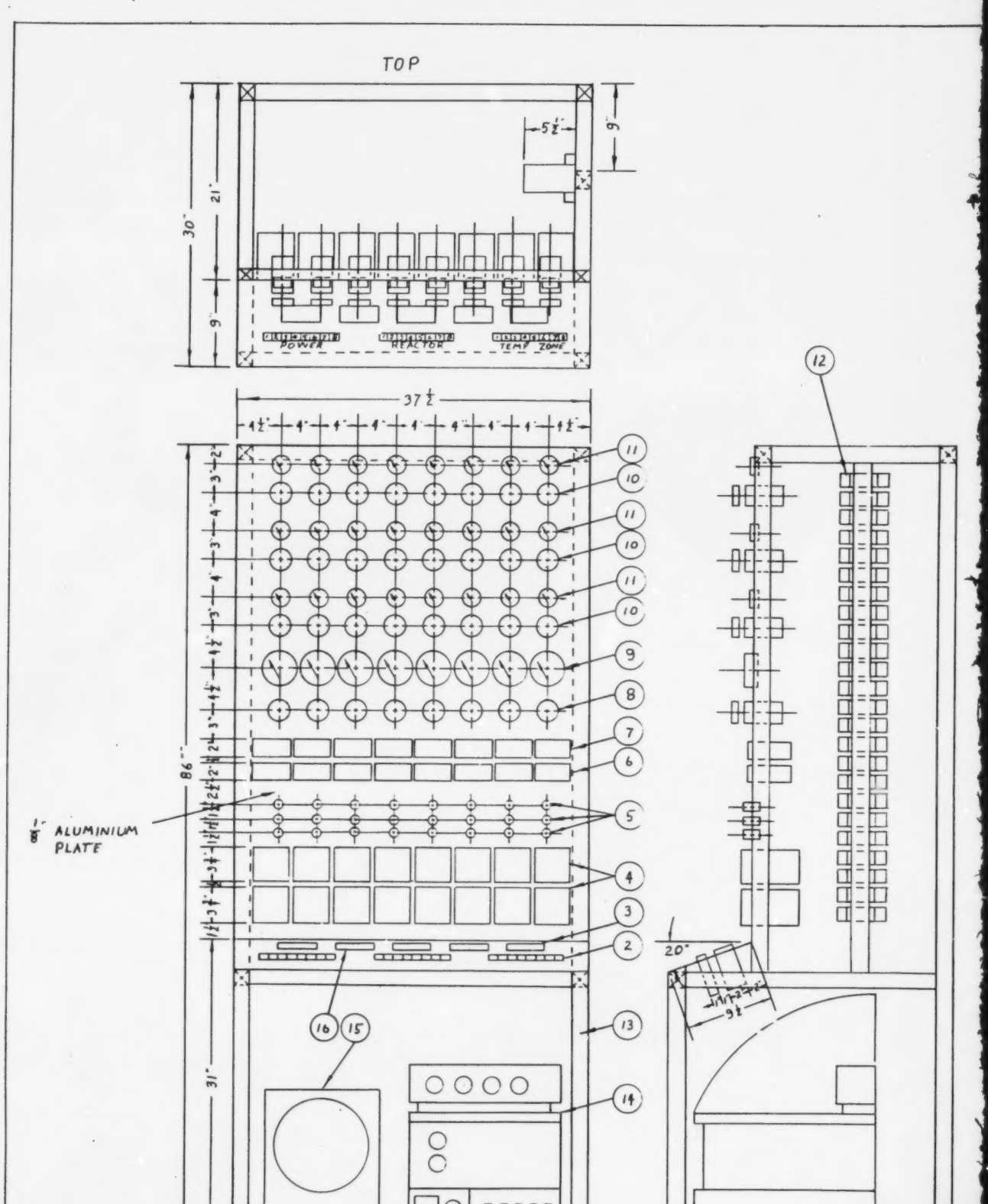
FRONT

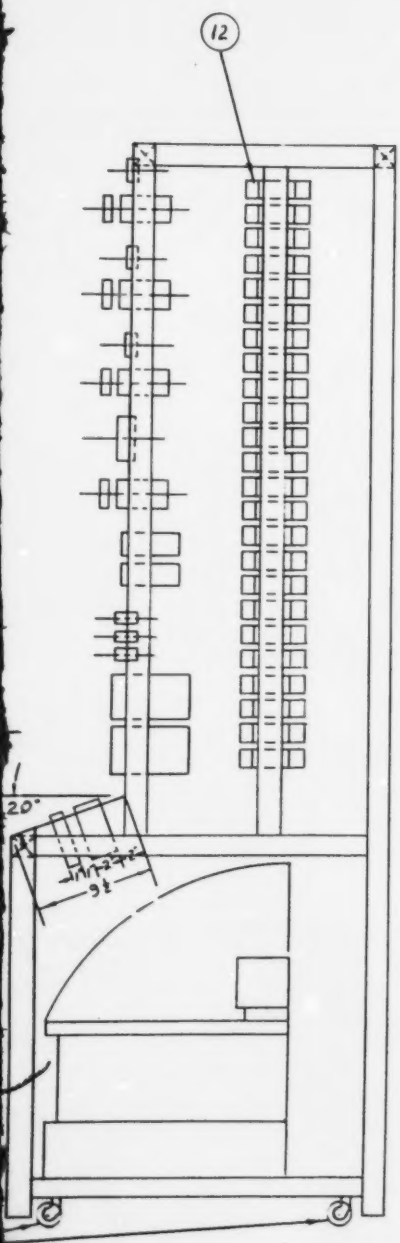
NOTE:
FOR DETAILED CONFIGURATION OF EACH OF THE FOUR SECTIONS SEE DRAWINGS NUMBERS THREE FOUR AND FIVE

QUEENS UNIVERSITY
CHEMICAL ENGINERING
KINGSTON, ONTARIO

APPARATUS LAYOUT

NAME D. OOSTEN	DRAWING NO. 2
DATE SEPT. 27/83	CHECKED BY B. W. Wojciechowski


TOP
5½"
9"
30"
21"
9"
POWER
REACTOR
TEMP ZONE
37½"
1½" 4" 4" 4" 4" 4" 4" 4" 4" 1½"
86"
2" 3" 4" 3" 4" 3" 1½" 1½" 2" 3" 2½" 2½" 1½" 3½" 3½" 1½" 31" 3"
1/8" ALUMINIUM PLATE
11 10 11 10 11 10 9 8 7 6 5 4 3 2 16 15 13 14 1
12
20"
9½"
FRONT
SIDE



SIDE

ITEM	QTY	DESCRIPTION	MFG'S NO.	REMARKS
16	1	DIGITAL THERMOMETERS	199KC	OMEGA TYPE K 3½ DIGIT
15	1	WET-TEST METER	11-166-4	FISHER 680 L/hr
14	1	GAS CHROMATOGRAPH	AGC III	CARLE FOUR PACKED COLUMNS, HYDROGEN TRANSFER
13	70'	CANTRUSS FRAMING	RE 6-DC	ELECTROVERT
12	24	MASS FLOW CONTROLLER -316 SS	UFC-1000	UNIT INS. 0-5 SLPM ¼" TUBE CONNS. (SWAGELOK)
11	24	PRESSURE GAUGE -316 SS	———	MATHESON, 2½" DIAL 0-600 PSI RANGE ⅛" NPT
10	24	PRESSURE REGULATORS -316 SS	IR 103	VERIFLO 0-600 PSI RANGE ¼" NPT(F)
9	8	PRESSURE GAUGE -316 SS	———	MATHESON, 3½" DIAL 0-600 PSI RANGE ¼" NPT
8	8	BACK PRESSURE REGULATORS -316 SS	BPR-40-SS	VERIFLO 2-600 PSI ¼" NPT(F)
7	8	TIME INDICATORS	636-Y	CRAMER CONRAC RESETTABLE 5-DIGIT 120 VAC
6	8	TOTALIZER READOUT	7998	VEEDER-ROOT 6-DIGIT RESET, LCD
5	24	PRECISION POTENTIOMETER	3610S-1-502	BOURNS 10 TURN 5K Ω
4	16	TEMPERATURE CONTROLLERS	1602	OMEGA DIGITAL SET POINT TIME PROPORTIONAL
3	5	DIGITAL READOUT	PI2456	ANALOGIC 3½ DIGIT 0-5 V DC
2	3	MULTI-SWITCH	90084806	ELECTRO SONIC LOCK-OUT 8 STATION, INTERLOCK
1	4	UNIVERSAL CASTERS 2" DIA	46-0629X-4	CANADIAN TIRE STEEL PLATE MOUNT, RUBBER WHEELS

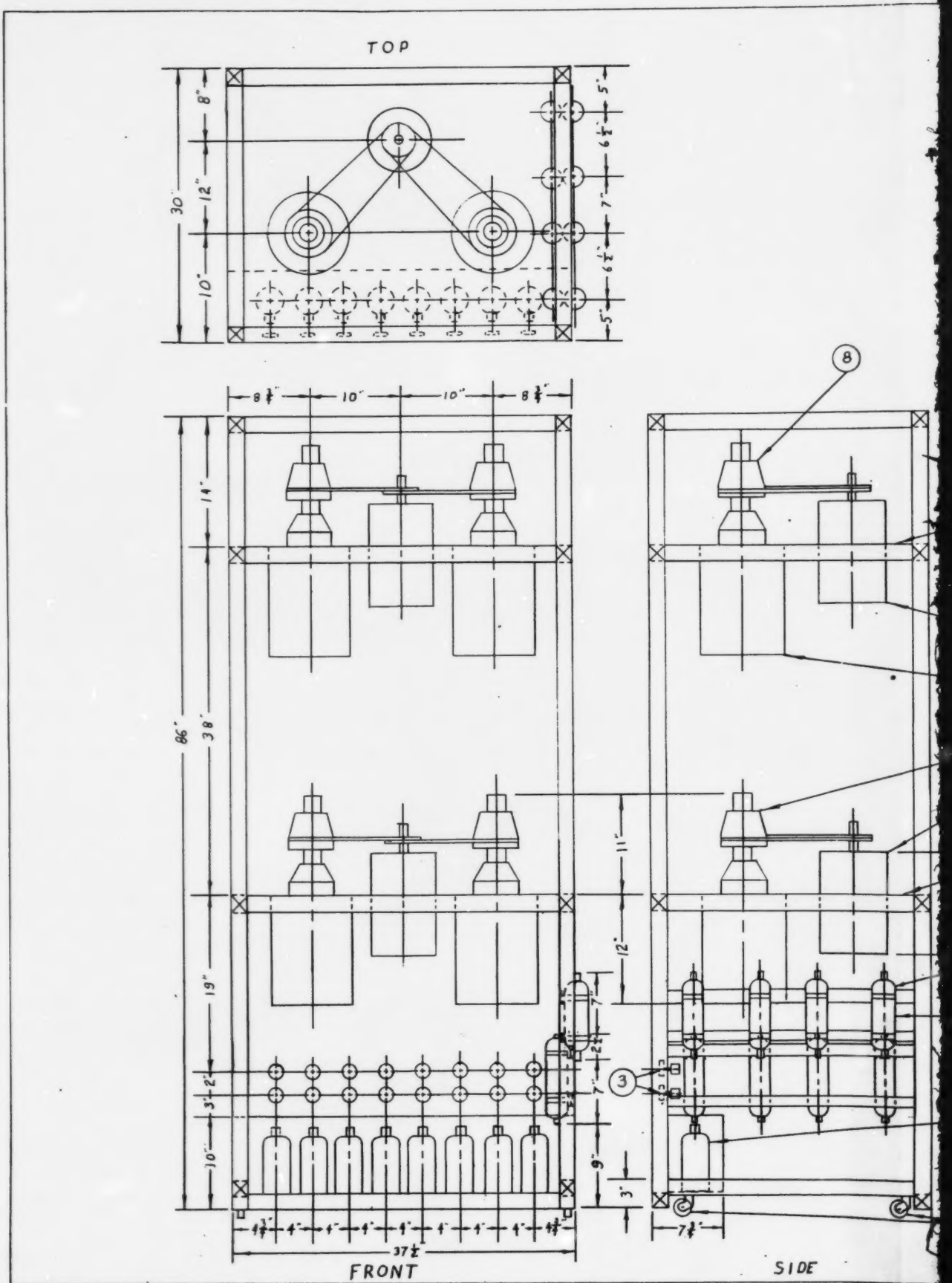
PARTS LIST

QUEENS UNIVERSITY
CHEMICAL ENGINERING
KINGSTON, ONTARIO

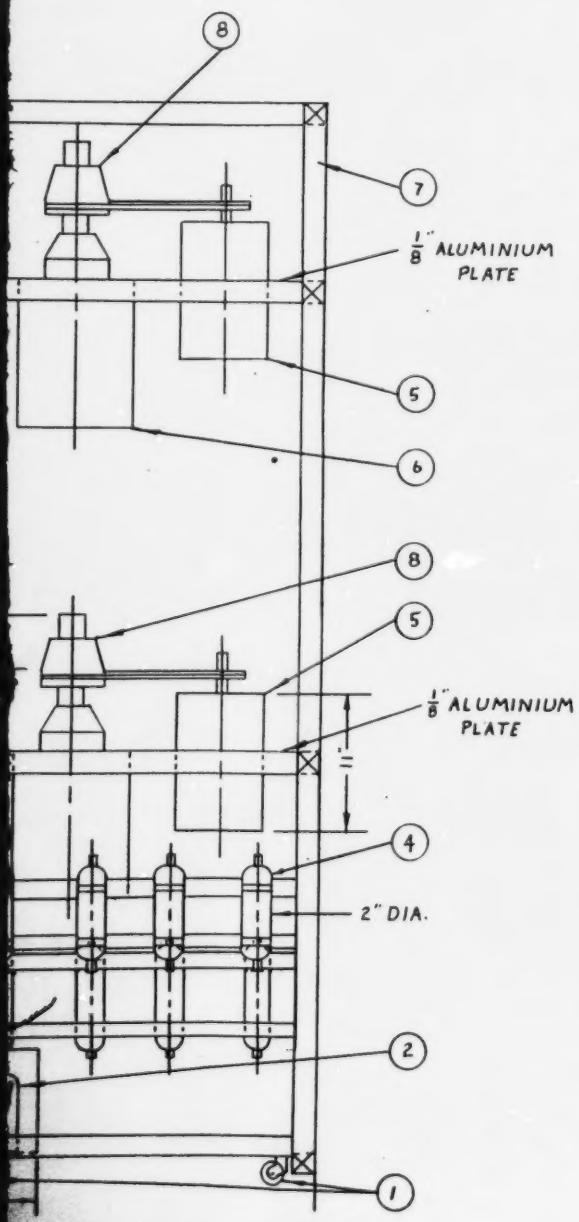
SECTION ONE LAYOUT

NAME	DATE	SCALE
O. OOSTEN	SEPT 27/83	3"-2'-0"

CHECKED BY	DRAWING NO.
B W Uhrich	3


TOP
30"
8"
12"
10"
5"
6½"
7"
6½"
5"
8½"
10"
10"
8½"
14"
86"
38"
19"
3"
2"
10"
11"
12"
7"
2½"
7"
9"
3"
8
3
1½"
4"
4"
4"
4"
4"
4"
4"
1½"
37½
7½"
FRONT
SIDE

NOTE:
SECTION TWO AND THREE ARE THE SAME LAYOUT. FOR TOTAL QUANTITY OF PARTS MULTIPLY BY TWO.



SIDE

ITEM	QT'Y	DESCRIPTION	MFG'S NO.	REMARKS
8	4	MAGNE DRIVE II	1.5-1.0-5KSS	PARR ENGINEERS
7	70'	CANTRUSS FRAMING	RE6-DC	ELECTROVERT
6	4	CATALYTIC REACTOR -316SS	4522	PARR BENCH TOP 1 LITER 500 PSI @ 500°C
5	2	UTILITY MOTOR	56-4556	CANADIAN TIRE ¼ hp 115/230 V 3450 RPM
4	8	SAMPLING CYLINDER -304 SS	304L-HDF-4-500	WHITEY 500 mL CAPACITY ¼" NPT(F) CONNS.
3	16	BELLOWS VALVE -316 SS	SS-4H	NUPRO ¼" TUBE CONNS (SWAGELOK)
2	8	LABORATORY BOTTES	B7509	NALGENE 500 mL NARROW MOUTH
1	4	UNIVERSAL CASTERS 2" DIA	46-0629X-4	CANADIAN TIRE STEEL PLATE MOUNT, RUBBER WHEELS

PARTS LIST

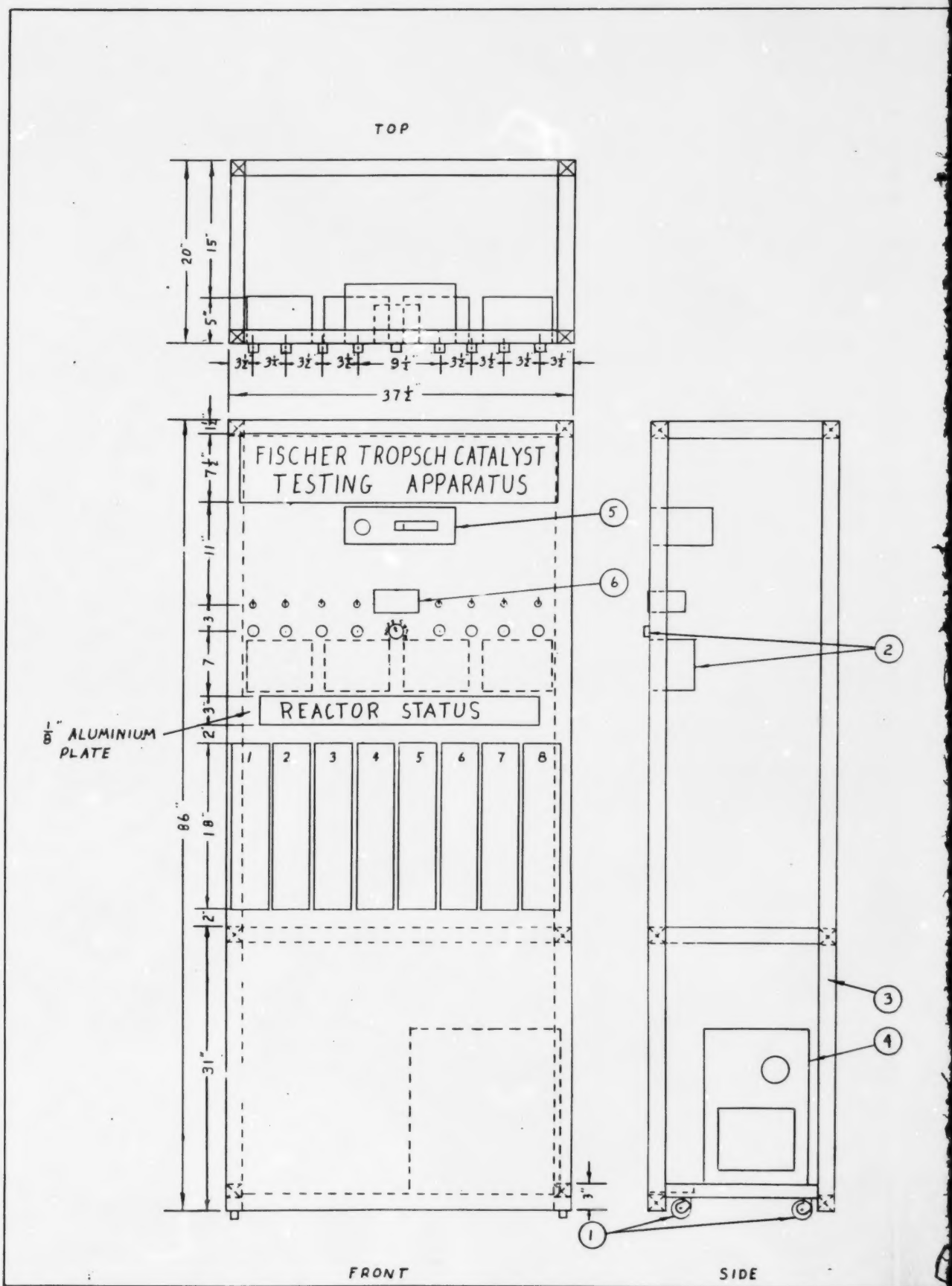
QUEENS UNIVERSITY
CHEMICAL ENGINERING
KINGSTON, ONTARIO

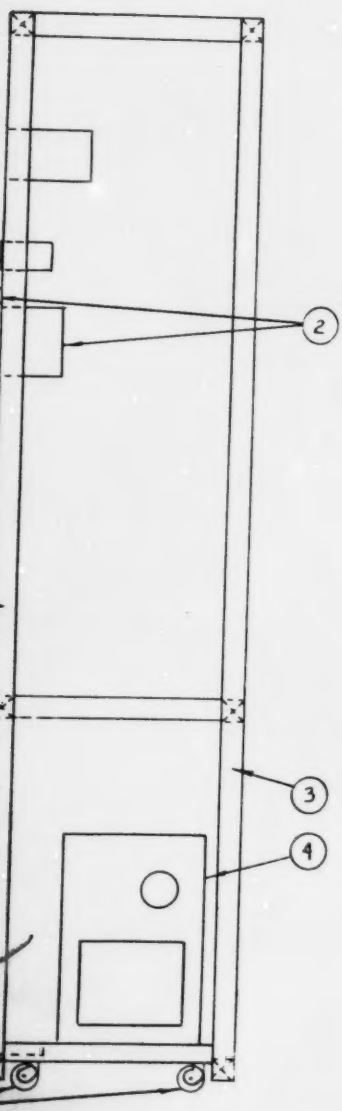
SECTION TWO AND THREE LAYOUT

NAME	DATE	SCALE
O. OOSTEN	SEPT. 27/83	3" = 2'-0"

CHECKED BY B W. Wojciechowski

DRAWING NO. 4


TOP
FISCHER TROPSCH CATALYST
TESTING APPARATUS
REACTOR STATUS
1/8" ALUMINIUM PLATE
1 2 3 4 5 6 7 8
20"
15"
5"
37½"
86"
18"
31"
11"
7"
7
3
2
3"
1
2
3
4
5
6
FRONT
SIDE



SIDE

ITEM	QTY	DESCRIPTION	MFG'S NO.	REMARKS
6	1	R.P.M. DIGITAL READOUT	1709 CR	POWER INSTRUMENTS LED DISPLAY
5	1	PURE AIR MONITOR	CZ-109	CALIBRATED INSTRUMENTS
4	1	REFRIGERATED CHILLER	K-1283-00	NESLAB 1910 BTU/h. TEMP. -5° to +35°C
3	50'	CANTRUSS FRAMING	RE6-DC	ELECTROVERT
2	8	SPEED CONT.	D-3701-5	RELIANCE IMPAK CONTROL ± 3 HP.
1	4	UNIVERSAL CASTERS 2" DIA	46-0629X-4	CANADIAN TIRE STEEL PLATE MOUNT, RUBBER WHEELS

PARTS LIST

QUEENS UNIVERSITY
CHEMICAL ENGINERING
KINGSTON, ONTARIO

SECTION FOUR LAYOUT

NAME	DATE	SCALE
O. OOSTEN	SEPT 13/83	3" = 2'-0"

CHECKED BY	DRAWING NO.
B Willy Wickenden	5